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Evaluation of Low Power Mobile Devices in Intelligent Transportation Systems

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ABSTRACT

The paper discusses the use of mobile devices like smart phones and tablets in Demand Responsive Transit (DRT). The paper will specifically focus on a special DRT called "Flexible Bus Systems" (FBS). In FBS the routes of the buses are so flexible that even they can take a short route to pick up the passenger waiting at the bus stops by skipping the bus stops where no passenger is waiting to ride the bus and no passenger wants to drop off. The major objective of using the mobile devices in FBS is to provide passengers with real time information of buses, facility of booking bus tickets on the fly using their mobile devices. Furthermore, NFC tags are used to help tourists get the information about the city along with bus schedules on their NFC enabled smart devices.

KEYWORDS*:* Demand Responsive Transit; Intelligent Transportation Systems; Flexible Bus Systems; Near Field Communication.

1. INTRODUCTION

Technology is playing its part in every field of life in order to improve the quality of life for humans. Intelligent Transportation Systems (ITS) are transportation systems which are smart enough to provide information to drivers and vehicles on road. Demand Responsive Transit (DRT) is a type of ITS in which public transportation is made intelligent and efficient to improve the wait time and ride time of the passengers at stops and buses respectively. Flexible Bus System (FBS) is a specially designed DRT in which not only the wait time and ride time of the passengers is improved but it also provides real time information about buses and bus stops to the passengers. One of the most important aspects of FBS is that it uses short range wireless technology, ZigBee to transfer information from bus stops to buses which significantly reduces the overall cost of the system. Furthermore, low power attribute of ZigBee reduces the overall power consumption of the system which makes it an excellent choice to be used in transportation systems in developing countries where cost and power are major players in development and deployment of systems.

The paper will go into detail of discussing how mobile devices can make FBS much more information rich and efficient for passengers. Furthermore, use of NFC tags on the bus stops will help tourist get information about the city and exact schedule for the buses based on each bus stop. This will not only improve the user experience but also help tourists in moving within the city without hiring expensive tourist guides.

The remaining sections of paper are organized as follows: The next section provides an overview of the current state of the art and advancements in the field of Intelligent Transportation Systems (ITS). Section III presents the proposed system model which covers the complete design and implementation features of the DRT. While the FBS cloud environment is elaborated in section IV and information dissemination for member and non member scenario in section V. Experiments conducted using various wireless technologies and SNR observed for a variety of devices are discussed in section VI and VII respectively. And finally the concluding remarks are stated in section VIII.

2. **Related Work.** This section will review some important aspects presented by a wide range of researchers for the control of demand responsive transit systems in vehicular communication. Demand responsive transit has appeared to be a most effective mean to disseminate information to various stakeholders in Intelligent Transportation Systems. There may be a variety of algorithms used in DRT due to the sensitivity of the system

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as the information keeps on updating continuously based on the runtime changes of the schedule and the latest information needs to be sent and received at each device in DRT.

Researchers have put a lot effort on increasing the overall efficiency of the demand responsive transit by applying assorted techniques considering several parameters like vehicle and passenger information and using different information systems but a relatively less consideration has been paid on consumer oriented personalized DRT's to enhance the user experience with the help of Personalized Demand Responsive Transit (PDRT). Khattak [1] presented the idea of PDRT and they have conducted several surve

ys to take the input of the passengers towards DRT to make them personalized as per the wishes of the travellers of a particular area.

Environmental impacts are also crucially significant for demand responsive transit in an area that has also been given a little prior attention. Dessouky [2] have taken into account the environmental factors in vehicle routing and schedule optimization. They presented a methodology for joint optimization of cost, service and life cycle environmental consequences in vehicle routing and scheduling developed for their demand responsive transit system.

Li [3] suggested the idea of feeder transit system in which analytical and simulation models are developed to assist the planners in deferent type of decision makings regarding when to choose demand responsive and fixed-route transit systems and whether and when to switch from one to another during a day. The choice of the best policy is made keeping in view the optimum quality of service in terms of weighed sum of customer walking time, waiting time and ride time.

One of the significant area of research is productivity in operating practices in a demand responsive transit. A contribution is by Quadrifoglio [4] on productivity items of specific operating practices which are implemented by DRT providers widely. The effect of zoning vs. non-zoning strategy is observed by them and time window settings are done on different performance parameters, like deadhead miles, total trip miles and fleet size. They constructed A simulation model of the operations is constructed by them for the DRT providers which is based on DRT data in a particular countryside.

Draw backs of conventional bus and private taxi services are considered one of the main reasons for the popularity of the demand responsive transits. Mageean et al. [5] have introduced the telematics-based DRT services and they were able to evaluate set of DRT technologies and operations in urban and rural areas and presented the results based on their experiments that argue in the favour of low cost solutions of DRT by not using all rural stops at every ride.

3. **System Model.** As illustrated in Fig. 1, a control center would be in-charge of all the buses and the bus stops. All the bus schedules will be transferred to the buses through control center via bus stops. Each bus and the bus stop are equipped with a short range wireless technology, ZigBee modules which has a maximum range of 100m. As soon as the bus enters the communication range of the bus stop, the information from the bus stop (schedule for buses, no. of passengers waiting on the bus stop and shortest path for buses etc.) will be transferred to the bus [6].

The bus stops are intelligent enough that they contain all the information about the buses and their arrival time at the bus stop. As soon as, a passenger arrives at the bus stop, he can get all the information about the buses and the bus stops personalized to him. These intelligent bus stops are information rich for the tourists as well, since they contain all the updated information about the famous places of the city [7].

In this traditional Flexible Bus System, the passengers are still required to go to the bus stop to get all the information about the buses. In order to make this system more efficient and user friendly, this paper proposes efficient use of mobile devices in Flexible Bus System. As illustrated in Fig. 1, the user can get all the information about the bus stops, famous places of the city, maps, schedules and routes for the buseson his smart device (smart phone, tablet, netbook) while sitting at home. Furthermore, if a tourist carrying a smart device reaches a bus stop to ride a bus, he cannot only use the bus stop to get the information about the famous places but also use his smart device to transfer all the related information from the bus stop to the smart device using NFC (Near Field Communication). This will allow the tourist to navigate through the city without going to the bus stop and collecting the information again and again [8].

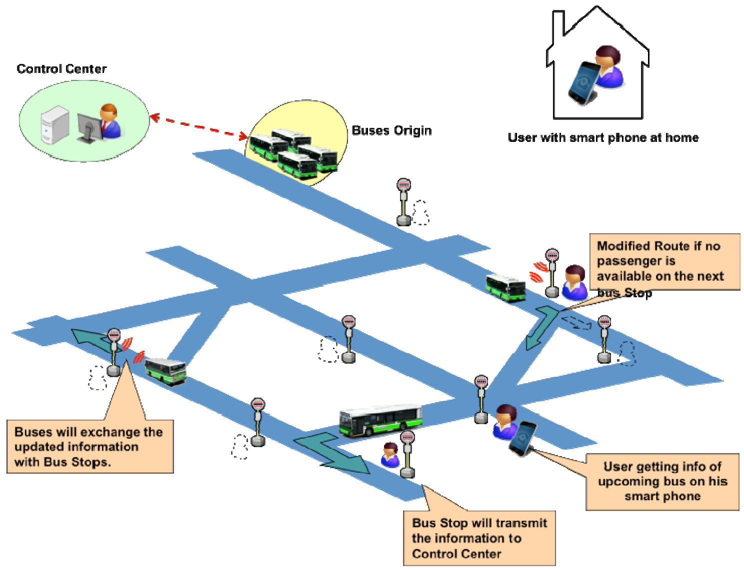

Figure 1. Proposed system model for efficient use of mobile devices in FBS

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4. **FBS Cloud.**

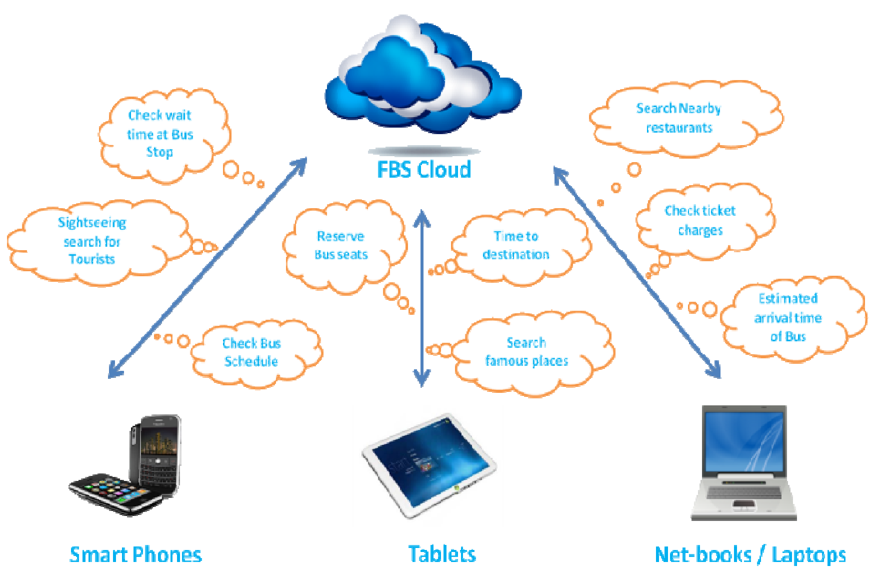

Figure. 2. Flexible Bus System cloud model

Figure 2 illustrates the cloud model for Flexible Bus Systems. We call it, FBS Cloud. In order to make the information available on mobile devices, this paper proposes the use of a cloud which contains all the information like bus schedules, bus stop coordinates, passengers at the bus stop, city information, maps and information of tourist's places of the city etc. Control center is the in-charge of all the information of the system, so all the information will be updated to the cloud through control center. This information in cloud will be available to all the passengers at home or at the bus stop.

If a passenger wants to see the schedule of the bus stop while at home, he can open FBS app on the smart device which contains all the information about the buses e.g., bus timings, routes, bus numbers, bus capacity, seat availability and ticket charges etc. This information will be displayed to the passenger in real time. Similarly, the passenger at bus stop can get the information from either the bus stop or from his smart device.

5. **Information Dissemination.** FBS provides the facility of disseminating the information in a personalized way. A passenger can get the information on his smart device based on his preferences. In order to make this possible, passengers are divided into two categories; members and non-members. Below are the details for each category:

5.1. **Members.** FBS has the facility to provide personalized information to the passengers. Such passengers will have to get registered to the system to become a member. Each registered member can get benefitted from the system by getting some extra information on their smart devices from the system like History, Frequently visited places and getting updated information of buses and bus stops at home without even visiting the bus stops. Figure 3 illustrates the model of FBS cloud for registered members.

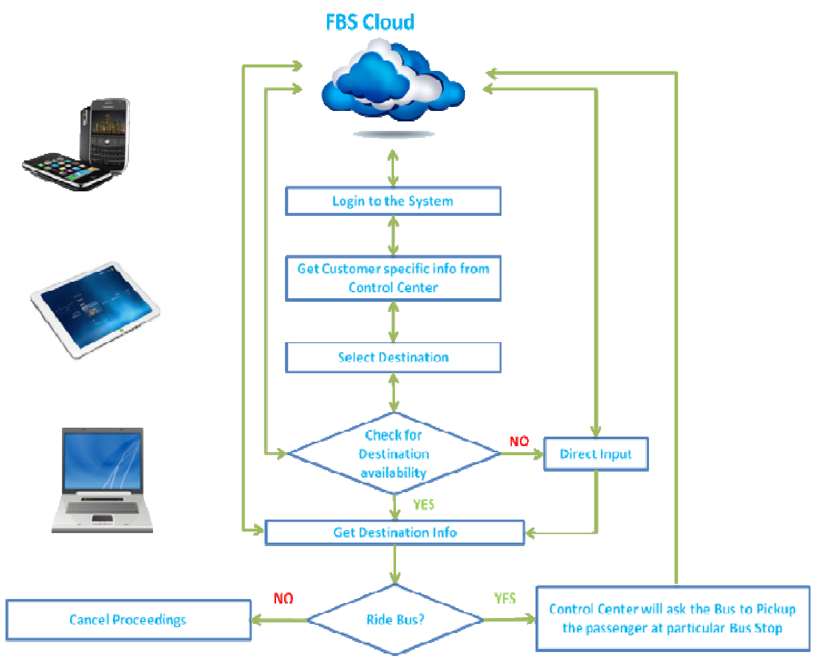

Figure 3. Flexible Bus System cloud model for members

As illustrated in Figure 3, after login to the system from the smart device, the members can select their destination and system will provide destination information like availability of buses, vacant seats, arrival time of bus at nearest bus stop, time to destination and fare etc. Member can then select whether he wants to ride the suggested bus or not. If 'Yes' the information will be sent from the smart device to the control center wirelessly using the Internet and control center will inform the particular bus to pickup the passenger from the mentioned bus stop [9]. If, however, member selects 'No' the proceedings will be canceled.

There are many benefits for the members like they can view the history of their previous trips, recent famous places visits, discounts and pre-paid and post-paid ticket facility etc. Furthermore, each member will be issued a membership card (NFC based smart card) which will contain information about the customer and will also serve as a discount coupon if customer decides to ride the bus from the bus stop.

5.2. **Non-Members / Tourists.** FBS is flexible in a sense that it facilitates not only members but non-members and tourists as well. If a customer is not carrying a membership card for FBS, even then he can use the system and ride the bus to reach his destination. Fig.4 shows the FBS cloud model for non-members and tourists.

As illustrated in Figure 4, non-members and tourists can use this system but they have some limitations. Non-members can select the source and the destination and check for available buses, their timings, routes and seat availability. If customer decides to ride a particular bus, he can select it which will bound the bus to pick up the customer from the bus stop by the control center. However, non-members will be limited to select the destination by entering the destination name and they do not have pre and post-paid ticketing facility. Furthermore, since they won't be issued a membership card, so they cannot avail discounts on tickets.

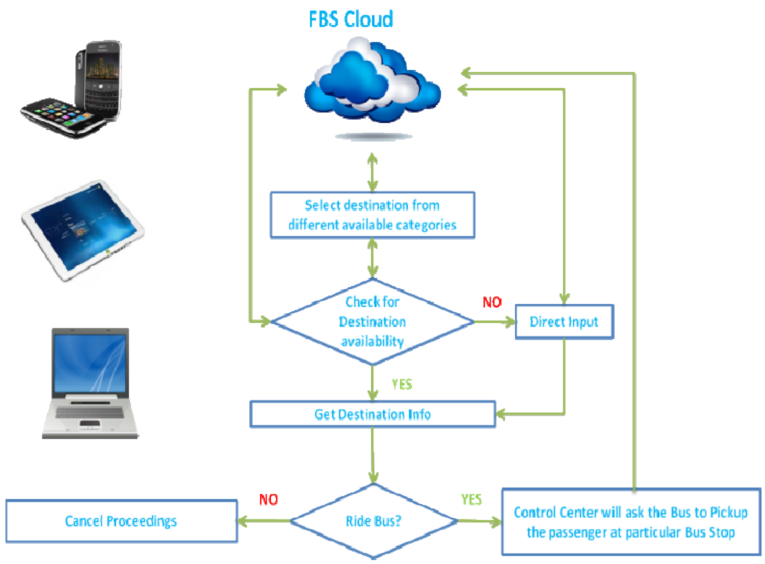

Figure 4. Flexible Bus System cloud model for non-members

6. **Wireless Communication.** Communication in mobile devices is convenient since they can communicate over the air (wirelessly) through internet. However, when communication is done through cloud, it is very important that information is fast and reliable. Customers are using their mobile devices to check bus information (routes, schedules and seat availability); most recent and updated information should reach the customer. This information relies majorly on wireless connection. For the purpose of this research, various wireless connections are tested against this system. Below are results for various wireless connections when few bytes of information is sent from the device to cloud and vice versa.

Table I: Comparison of wireless connections for transreceiving data to and from cloud

	No. of bytes	Time in seconds	Error percentage
Wi-Fi	120	10	2 %
2G	120	14	11 %
3G	120	11	3 %
Wired	120	6	0 %

Table above shows the results of various experiments conducted to test the speed and reliability of various connections wired and wireless against the system for sending the receiving data to and from the cloud using mobile devices. As illustrated in the table, wired connection offers the most speedy and reliable connection for this system, however, 3G and Wi-Fi connections are also fast enough to transfer the data. Furthermore, the error percentage in the table represents the packet data error, which seems to be 0% for wired connection and 2% for Wi-Fi.

7. **Signal to Noise Ratio.** In order to provide a system that facilitates passengers by providing them information about the buses and their routes on their mobile devices using Internet, it is very important to actually consider the quality of signals for that particular device. In this system, passengers can be anywhere, e.g., home, shopping mall, roads or offices. In order to calculate the quality of the signals for passenger's device, Signal to Noise Ratio is very important. We used Shannon's capacity formula for calculating the signal strength of mobile device. Below is the Shannon's capacity formula:

$$C = B \log_2(1 + SNR) \quad (1)$$

In above equation, 'C' is the channel capacity, 'B' is the bandwidth and 'SNR' is the Signal to Noise ratio. SNR can be calculated by the formula below:

$$SNR = 10^{SNR_{db}/10} \quad (2)$$

Below are the results obtained from various experiments using above mentioned formula.

Table II: SNR for various devices at different places

Vendors	SNR (dB)	Location	PHY mode
iPhone	-64	Mall	802.11n
Nexus 4	-54	Mall	802.11b
Samsung Galaxy	-60	Mall	802.11b
iPad	-66	Mall	802.11b
iPhone	-72	Road	802.11n
Nexus 4	-80	Road	802.11b
Samsung Galaxy	-70	Road	802.11b
iPad	-74	Road	802.11b

8. **Conclusion**. In this paper we discussed our proposed system of using mobile device to send and receive information in a demand responsive transit. We presented our prototype system in which passengers can use their mobile device to get the information of the buses and their routes without even visiting the bus stop or ticket collection center. All the information provided to the passengers is the most updated information from the cloud. Flexible Bus System is a system in which buses are very smart even they can change their routes which depends upon the need. Since the bus routes are flexible, it is very important to inform passengers about the updated bus schedules. The proposed system in this paper enlightened the fact that passengers can be a part of the system even if they are not registered with this system. Furthermore, our experiments showed that quality of signal could be improved using Shannon capacity formula by calculating the Signal to Noise ratio. In this research we conducted various experiments for various devices at different locations to test the reliability of the system and our results are encouraging which makes our proposed system a next generation demand responsive transit system.

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